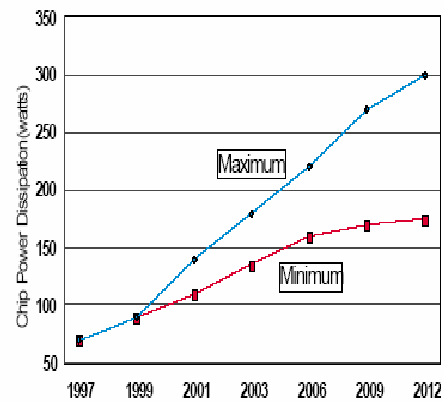
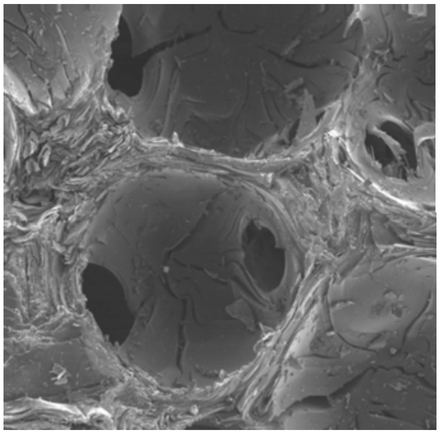
Carbon Foam for Cooling Power Electronics

Background

In recent decades, many performance improvements in electronic components, such as higher-power computer chips and power converters, have led to significantly increased heat generation at small size scales thereby requiring better strategies for microscale heat dissipation. In view of the projected chip power dissipation, modern heat dissipation devices must be capable of spreading and dissipating heat rapidly and efficiently to prevent localized hot spots and to ensure that the temperature of the Si-based electronic components does not exceed 125°C. Porous carbon foam, developed at the Oak Ridge National Laboratory (ORNL), has an extremely high specific conductivity, which, combined with its open, interconnected internal structure, has the potential for significantly reducing the thermal resistance of heat transfer devices. Measured cooling rates from a prototype air-water radiator made of carbon foam fins confirms that it has the potential to reduce the airside thermal resistance. The development of alternative devices that more fully utilize the internal structure of the foam have the potential to significantly increase heat transfer performance.



Projected chip power dissipation requirements



Electron micrograph of the Carbon Foam surface

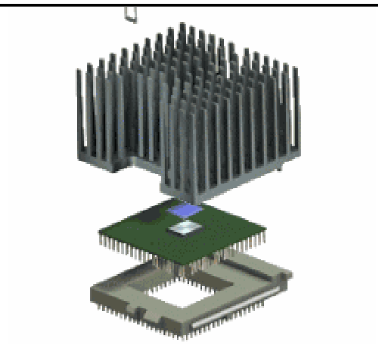
Benefits

- Smaller and lighter thermal management devices
- More efficient thermal management devices
- Simpler design and maintenance

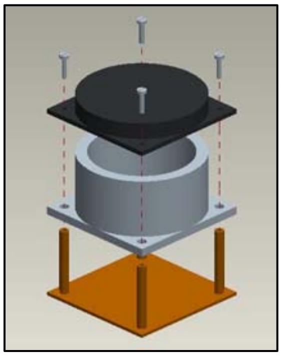
The Technology

A thermal engineering model to represent heat transfer from porous carbon foam has been developed for use in design processes for heat exchangers with finned tubes. Characteristic parameters for carbon geometries, specifically exposed surface absolute roughness, exposed surface area factor, effective thermal conductivity, surface area to volume ratio and permeability, are calculated with a simple geometric model of a unit cube with spherical void surrounded by carbon-foam ligaments. The airside thermal resistance is calculated with an engineering model derived from conventional correlations that are extended to represent the effects of the porous carbon foam. Most importantly, the airside convective heat transfer was modified to account for the effects of roughness due to the porous surface and, to represent the recruitment of effective surface area due to interstitial flow through the carbon matrix. Model predictions for the air-water carbon foam heat exchanger developed and tested at ORNL suggest that the present thermal-engineering model calculates heating conservatively, specifically about 11% less than the measured heat load.

The development of a similar engineering model for investigating the potential of carbon foam in electronic heat dissipation devices led to the consideration of an alternative design in which all of the cooling air is forced through a thin cylinder of foam. This simple configuration was shown to significantly out-perform conventional CPU heat sinks and similarly designed aluminum foam devices. This suggests that with further investigation and development, porous carbon foam could be used to meet the increased demand for higher, more efficient heat dissipation.



Conventional heat sink for computer CPU



Alternative configuration for carbon foam CPU heat sink

	Conventional Heat Sink	Alternative Carbon Foam Heat Sink (ACFHS)	ACFSH Design with Al – 6101 Foam
Cylinder/Fin Height	31.6 mm	35 mm	35 mm
Base Size	58 × 58 mm	55 × 55 mm	55 × 55 mm
Number of Fins/Cyls.	19	1	1
Thickness of Cylinder/Fins	0.8 mm	5 mm	15 mm
Porosity	N/A	80%	92%
Pore Diameter	N/A	200 μm	N/A
Fan Power Input	3/5 W	3/5 W	3/5 W
Pressure Drop	70/95 Pa	313/417 Pa	296/416 Pa
Heat Dissipated	100/120 W	240/270 W	60/64 W

Where Can I Find More Information?

DOE Technology Manager
Rogelio Sullivan
Department of Energy
202-586-8042
Rogelio.Sullivan@ee.doe.gov

ORNL Project Manager
David Stinton
Oak Ridge National Laboratory
865-574-4556
stintondp@ornl.gov

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